III.—EXPERIMENTAL.

On the Seat of Optical After-Images.[1]

M. Binet, in his "Psychologie du Raisonnement" (p. 43 ff.), quotes from M. Parinaud an experiment which, he thinks, proves the cerebral, instead of the retinal, seat of optical after-images. The experiment is as follows:

"Close and cover with the hand the left eye, and with the right eye fixate carefully for some moments a small square of red or black paper on a white background. If now the square of paper be removed, as by blowing it aside, a negative after-image of it will be seen by the right eye on the white ground. Now at the moment of blowing aside the square, close and cover the *right* eye and open the *left* one. After a moment the white field will darken, and on it will be seen the negative after-image."

This formation of an after-image in one eye and its subsequent appearance on the field seen by the other is taken by M. Binet as complete proof that the after-image lies not on the retina, but in the common cerebral center of vision for both eyes. Thence it is projected into the field seen by whichever eye is open. But he quite overlooks the possibility that the image lies really on the right retina and mingles itself with the field of the left eye. He takes it for granted that the phenomenon is seen by the eye which is open, and not by the closed one. That he is wrong in his deductions, and that in failing to consider the possibility above mentioned he has missed the true explanation of the phenomenon, it is the purpose of this note to show.

A serious difficulty in settling the question lies in the well-known impossibility of separating the visual fields of the two eyes. Whether one eye or both are open, whether they are focused on the same point or are held parallel, or squinted, or even jammed into all sorts of relative positions by fingers inserted into their sockets, the field of each will appear to coincide with the field of the corresponding portion of the retina of the other. If an after-image be formed on both together, one image only will be seen, whatever their relative positions; and if the image be formed on one alone, it will yet be seen in the corresponding portion of the field of the other, provided the brilliancy of the second field be not so great as to obscure the much weaker sensation of the image. In reality, in this experiment the after-image never does appear on the left field until the latter has so greatly darkened as to allow it to be seen; and in the periodical increases in brilliancy of the left field the image disappears.

It will thus be seen that a retinal seat of the after-image explains all the facts as easily as does a cerebral seat. Hence the assumption of the latter by M. Binet and others is entirely superfluous. We now hope to show that it is not merely superfluous, but impossible.

Although we cannot so separate the fields of the two eyes as to determine to which of the two the image belongs, yet we can determine that it does not belong to both. This may be done by observing the different effect on the image in interfering successively with the field of each eye. If the location of the after-image is in the cerebral sensory center, we should naturally suppose

[1]Read at the Graduate Course in Psychology at Harvard College, January, 1889.

that through whichever eye it may be seen it will present the same characteristics. If it does not, this must be due to disturbances persisting in the right retina or optic nerve. But if this be once granted it will easily be seen that these persisting disturbances in reality alone account for the after-image and all its phenomena. It is curious to note that M. Binet also mentions the differences in action of the two eyes, but without once thinking of this most natural explanation. The principal differences observed are these:

1. If after obtaining the after-image the right eye alone is opened, the after-image is seen at once on the white ground. If, however, the left eye alone is opened, the image does not appear until the left field is so darkened as to allow the image on the right retina to assert its presence. If now at this point the right eye is again opened, it will be found that its after-image is still plainly visible.

2. After obtaining the after-image, close both eyes. If now the left eye be opened, the image is dimmed or blotted out; and brightened when the eye is again shut. If the right eye alone is opened, the opposite effect is experienced; when the eye is open the image is brighter, when shut it is dimmed.

3. Leave now both eyes open after the image is obtained on the right one only. Thrust before the left eye a finger, pencil, or other opaque object, and no change (except a possible increase in brilliancy) will be observable in the after-image. If, however, the object be placed before the right eye, the image disappears temporarily and does not reappear, if at all, until the right retina is newly fatigued by its new background.

4. The following corroborative observation is due to Mr. E. C. Sanford: "If I brand a strong after-image on my right retina and project it on a white surface, I see it green; if I close the eye and project it on the dark field, I see it rose-colored. Now if I project it (as it seems) with the left eye (right eye closed, left open), I see it not green, but rose—exactly the tint in the closed eye, as I can see by quickly closing the left eye. I see it projected against the dark field—in other words, with the covered eye." In verifying this observation, I have found the following to be true in my own case: After obtaining the after-image from a red square of paper, if I project it on a white surface it appears *light* green; if I close both eyes and cover them thickly in such a manner as to shut out all external light, the after-image appears a much *darker* green; if, however, I merely close the eyes without covering them, so that considerable light can enter from without through the eyelids, the image then appears light rose, light blue, etc., according to circumstances. This affords a very conclusive test. I obtain a strong image with the right eye, then close and cover it, and open the left eye. Soon the left field darkens and the *dark green* after-image appears; this gives place to the *rose-colored* image if the covering is removed from the right eye and the eye kept closed; and this in turn to the *light green* if the right eye is opened. These three colors can be made to succeed one another indefinitely without in any way interfering with the open left eye, which alone, according to M. Binet, is the source of all the visual impressions present!

5. Retinal rivalry has been suggested by Prof. James as a test, and I also have found it reliable. After obtaining the after-image with the right eye, look at the background through colored pieces of glass, using both eyes simultaneously, but each looking through a

color different from that of the other; or by means of parallel vision, look with the right eye at a background of one color, with the left at one of another color. When the color of the left field is predominant, no after-image will be visible; when the right predominates, the image will be seen upon it.[1]

In the above experiments it will be seen that whatever be done to the left eye, the after-image suffers no change, except that of being brightened by diminishing the brilliancy of the left field, and dimmed or destroyed by increasing it. But whenever the right eye is interfered with in various ways, the image suffers corresponding modifications. These differences cannot be explained if we suppose the seat of the after-image to be cerebral. They are all easily explainable if the seat is retinal. M. Binet and others have made the great mistake of supposing that whatever they might see in the field of the left eye when it alone is open, is seen by that eye. That this is not necessarily so, and that in the phenomena presented by this experiment it is not possibly so, has been shown by the above facts. EDMUND B. DELABARRE.

Energy and Vision. S. P. LANGLEY. Am. Jour. of Science, 3d Series. Vol. XXXVI, p. 359.

Professor Langley has made a fresh determination of the brightness of the different portions of the spectrum. The investigation was made with great care, with a high sun, and errors from all possible sources were calculated and eliminated. The method chosen, after trial of others, was to determine how far away a screen carrying a portion of a table of logarithms had to be pushed in order for the figures to be just legible. The light from a slit, after passing through a collimating lens and a prism, was received on a silvered concave mirror, which formed a spectrum 90 mm. long in front of a second slit. Any color could be made to pass through this slit by setting a graduated circle; it then fell upon a black screen, through a hole in which, 1 cm. square, the table of logarithms was visible. The room was absolutely dark, and the position of the screen was got, by feeling notches, to within a centimeter. A variation of intensity of 225 times was had by the sliding screen alone. By changing the first slit and by introducing a photometer wheel, a variation a thousand times greater could be obtained. The selective absorption of silvered glass had been before determined by an ingenious method, and was now allowed for.

The results obtained are not easily compared with those of former observers (without making a graphical construction), for Langley's observations are taken at every .05 micron of wave-length, and those of Frauenhofer and Vierordt (the ones usually referred to) at Frauenhofer lines; but it seems plain that Professor Langley himself and his other three observers differ much more from each other

[1] It will be interesting to apply the following as yet untried test when a sufficiently sensitive hypnotic patient can be found who can obtain good after-images, but who has himself no theory as to "cerebral" or "retinal" seats. Let him obtain with the right eye a strong after-image, and then by suggestion paralyze completely the sight of that eye. If, then, no after-image is seen with the other eye open, it will prove that the cerebral center has nothing to do with the production of the image; if, however, the image is perceived, it will merely indicate that the paralysis of the right optic nerve has not been complete, and the experiment will have proved nothing.